Constellation X

The Constellation X-ray Observatory

TES Development at GSFC for the XMS

Caroline Kilbourne

Goddard Space Flight Center

X-ray TES development at GSFC

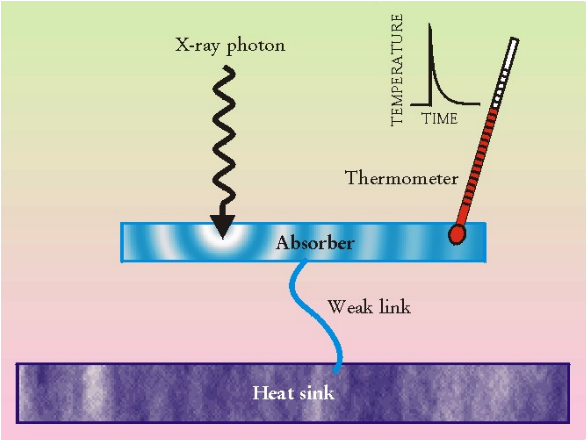
S. Bandler
K. R. Boyce
R. P. Brekosky
J. A. Chervenak
E. Figueroa -> MIT
F. M. Finkbeiner
N. Iyomoto
R. L. Kelley
C. A. Kilbourne
F. S. Porter
T. Saab –> U. Florida
J. Sadleir

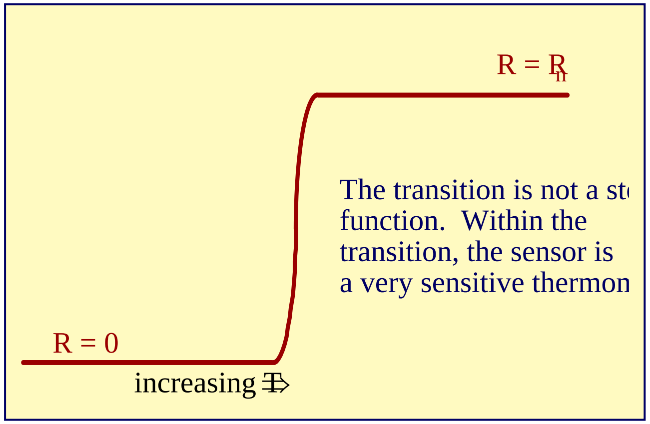
Principal areas of concentration:

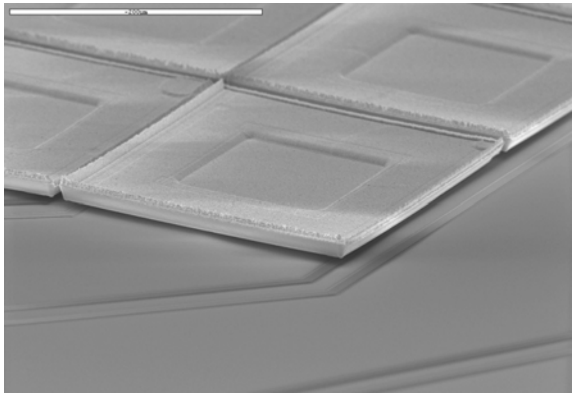
- **Continued development of close-packed TES arrays**
- **Characterization and optimization of absorber materials and interfaces**
- **Absorber process refinement**
- **Preliminary work on other form factor arrays**

Quick Reminder!

- **Superconducting Transition-Edge Sensors:**
  - Stable operation in the transition via electrothermal feedback
  - Use Mo/Au bilayers for Tc ~ 0.1 K
  - Si and Si-N used as structural materials
  - Micro-fabrication techniques are well established for Si and Si-N
  - Arrays are fabricated at the highest level of integration

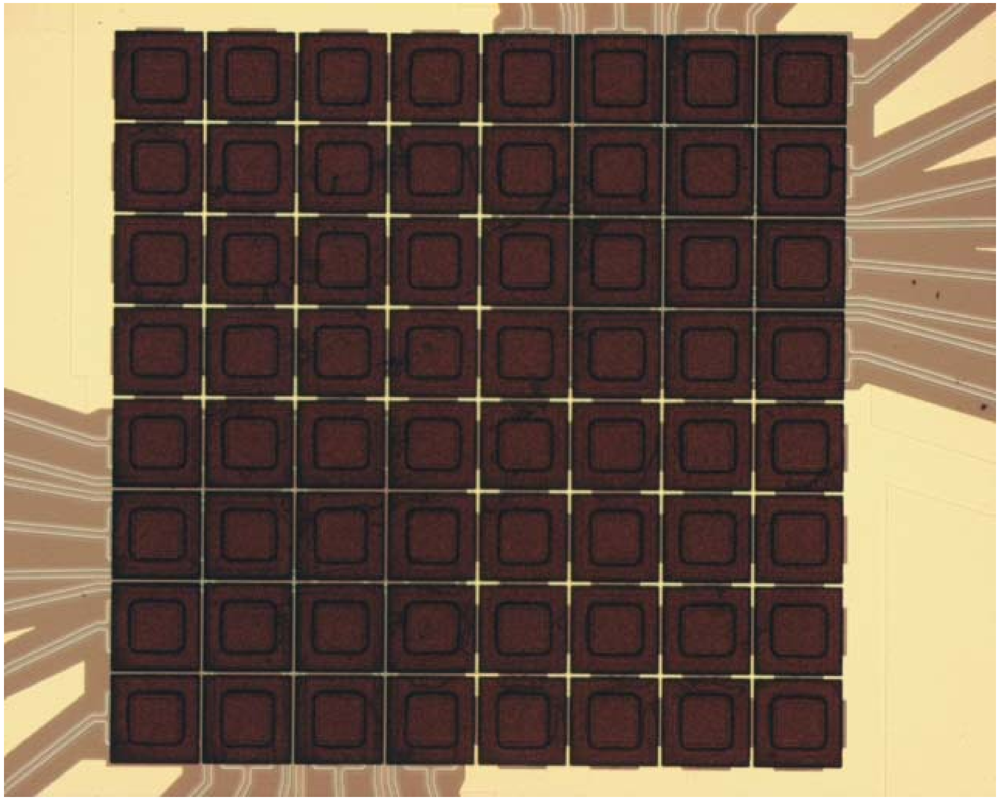


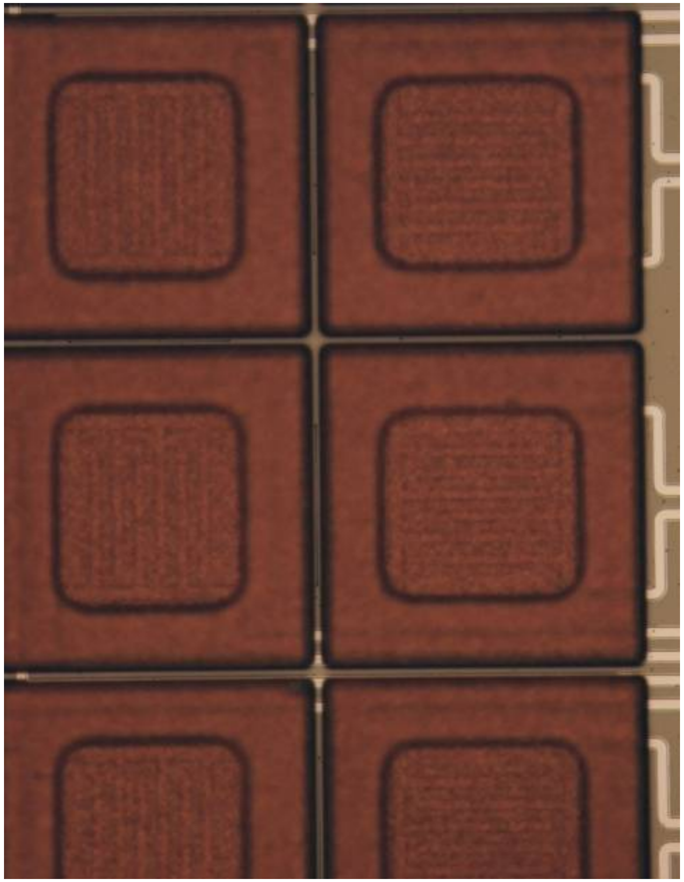




8x8 Arrays of TES Microcalorimeters with Bi/Cu Absorbers

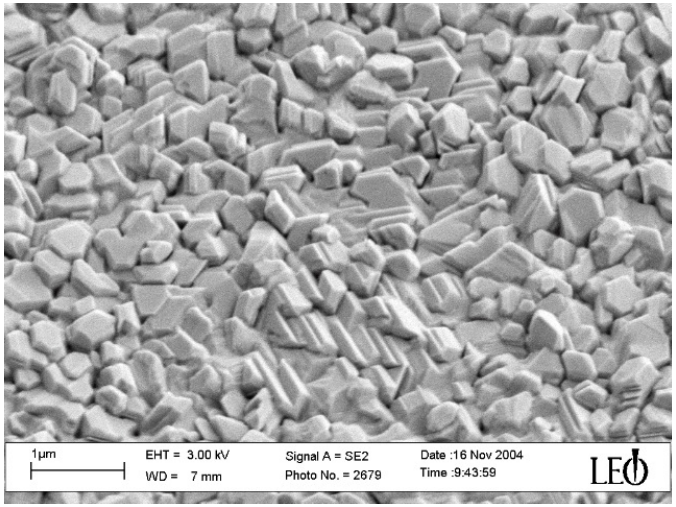
- Routinely produce 8x8 arrays with high-efficiency, high-fill-factor absorbers
- We are able to continue pixel optimization studies within these arrays
  - "single-pixel" development done in arrays only (5x5 and greater) for 5 years
- We are also able to study methods to address heat-sinking and thermal crosstalk

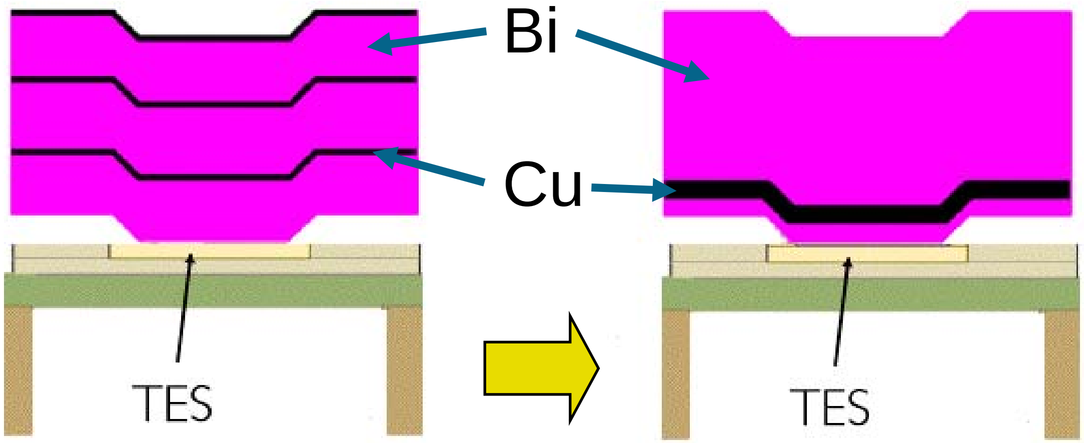




Absorber Optimization: Part 1

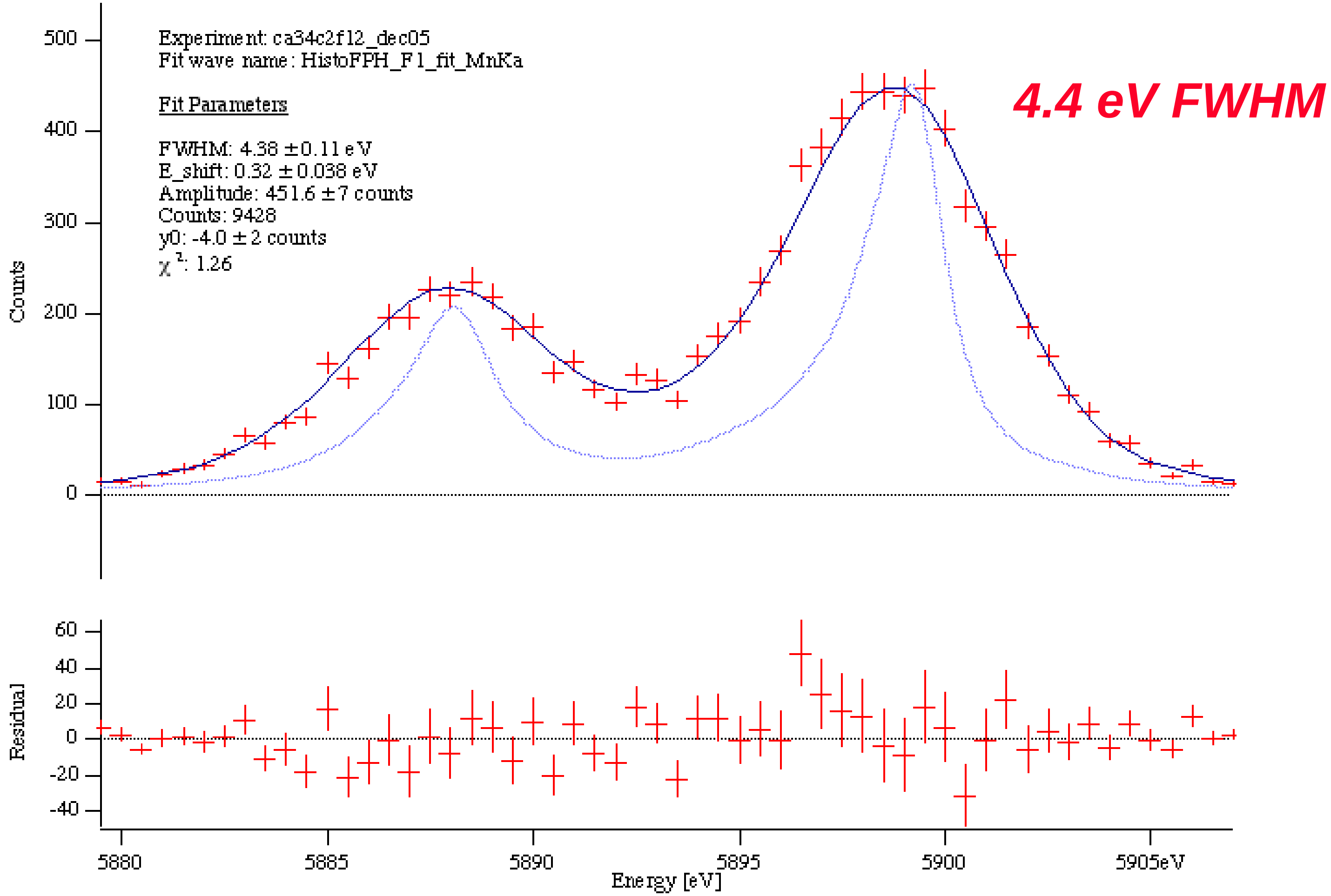
- **Overhanging absorbers**
  - Layers of Bi and Cu (or Au)
  - Bi for high absorption efficiency
  - Cu (or Au) for good thermal conductivity and for tuning the heat capacity
  - At the time of the transition from the 5x5 to 8x8 mask set, we rearranged the distribution of Bi (6.6 microns total) and Cu (0.6 microns total) to improve thermalization. The effectiveness of the thinner Cu layers had been diminished by Bi granularity on the same scale as their thickness.





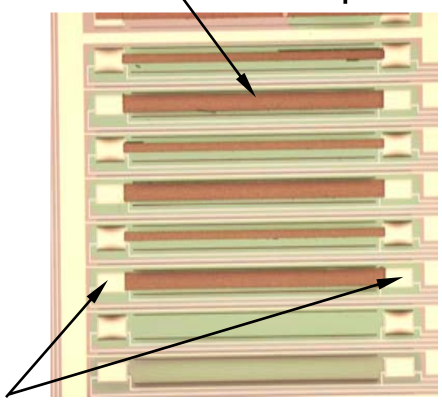
Resulting resolution

- **In this design, we have on several different pixels achieved resolutions at 6 keV between 4 and 5 eV FWHM.**



Diffusion analysis

- **We have used absorber strips between TES sensors, combined with diffusion modeling, to determine the diffusivity of our absorber material. (These strips also make pretty good imaging calorimeters, but that will be covered in Tali Figueroa's talk.)**
- **We have determined a diffusion constant of $2 \times 10^4\ \mu m^2/\mu s$.**
- **Feeding that into a diffusion model for the XMS pixels, preliminary indications are that it is adequate to minimize pulse shape variation across a pixel to the degree required by the the XMS spectral resolution requirement.**



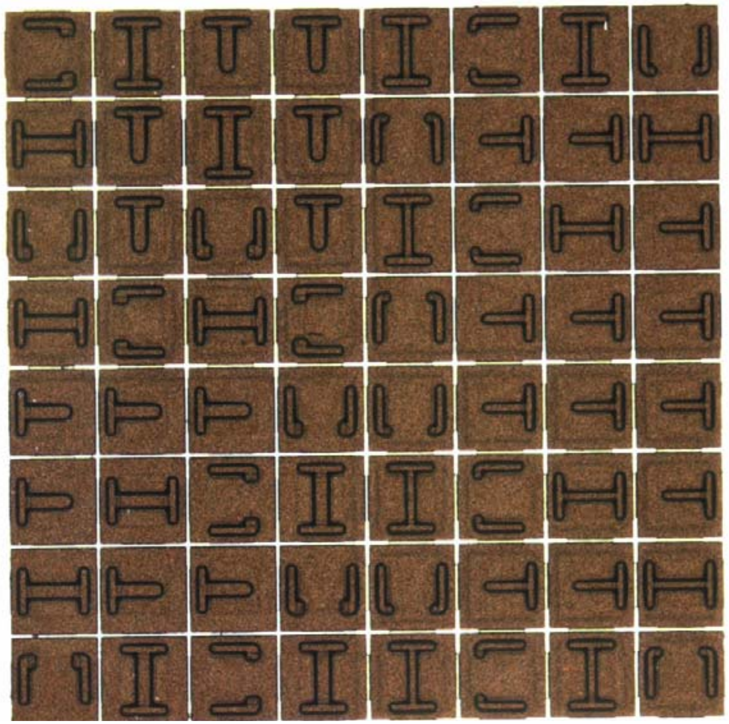
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Cabs = 1.43pJ/K
Gpb = 500 pW/K
alpha = 100
beta = 0.5
Tau = 234 usec
Resolution : 2 eV
If we bias at 20% Rmax/R = 2.12 and Delta(slope)max = 72%

Absorber Optimization: Part 2

- On the wafer of 8x8 arrays with 4 - 5 eV resolution, materials analysis revealed no chemical interaction between the Bi and the underlying TES. In other fabrication runs we observed formation of BiAu intermetallics at the interface or diffusion of Cu through the Bi and into the Au of the TES.
  - The problem with such interaction is that it alters the transition temperature of the Mo/Au bilayer from the value expected for the chosen Mo and Au thickness.
- Because of the variable nature of the phenomenon, we have designed absorbers that are cantilevered over the active part of the TES itself, only making contact at normal metal features.
- This process re-development coincided with a requirement to modify the absorber fabrication process that was imposed by our the photo-resist of our established process suddenly becoming commercially unavailable.
- Another advantage of using controlled contacts is that it would permit use of a good normal metal, such as Au, for the bulk of the absorber instead of just a thermalizing layer. The contact points have been designed to avoid electrically shorting out the TES with a low resistivity absorber.
  - Implicit in the optimal design of a pixel is the balance between sensitivity, non-linearity, and quantum efficiency.

First 8x8 arrays with new absorbers



- Introducing Au as the thermalizing layer, deposited first, before any Bi
- Using ion-milling instead of lift-off to define the gaps between pixels
- Process changes have been successfully demonstrated
- Test array with redesigned absorbers was just fabricated
- Not all required changes to the photo-mask set were made for this test run, but the next wafer will be a valid test of the devices

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Bigger pixels

- **During the XEUS merger studies, we started an investigation into larger pixels. These pixels were, in a sense, the precursor to our current work with the redesigned absorber process and the concept of moving the absorber out of direct chemical contact with the TES film**
- **In our first such devices, the large overhanging absorbers did not remain free, but touched the frame, thermally shorting the absorber and degrading the devices**
- **We intend to resume this development in the future, but it is not presently a high priority**

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Plan (as funding permits)

- Test and refine Bi/Au absorbers with controlled contacts
- Develop electro-plated Au absorbers, incorporate into new absorber design and test
- Study implementation of normal Mo as diffusion barrier between Bi of absorber and Au of TES in standard absorber design

>> robust process for reproducible and uniform arrays

- Characterize and quantify heat sinking and thermal crosstalk in 8x8 arrays
- Coordinate with NIST to jointly determine TES features, absorber structure, and array thermal design for optimized array.